

INDIANA'S THERMALLY INSULATED TEST ROAD

DECEMBER 1972 - NUMBER 46



BY

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JOINT HIGHWAY RESEARCH PROJECT

PURDUE UNIVERSITY AND
INDIANA STATE HIGHWAY COMMISSION

Technical Paper
INDIANA'S THERMALLY INSULATED TEST ROAD

TO; J. F. McLaughlin, Director December 28, 1972
Joint Highway Research Project
FROM: H. L. Michael, Associate Director Project: C-36-10G
Joint Highway Research Project File: 6-10-7

The attached Technical Paper "Indiana's Thermally Insulated Test Road" by James A. Horton, M. M. Bowers, and C. W. Lovell, Jr. has been accepted for presentation and publication by the Highway Research Board. It will be presented at the Annual Meeting in January 1973.

The Paper presents a summary of research data and findings presented to the Advisory Board in previously presented Interim and Final Reports.

The Paper is presented now for information and for approval of publication by the Highway Research Board.

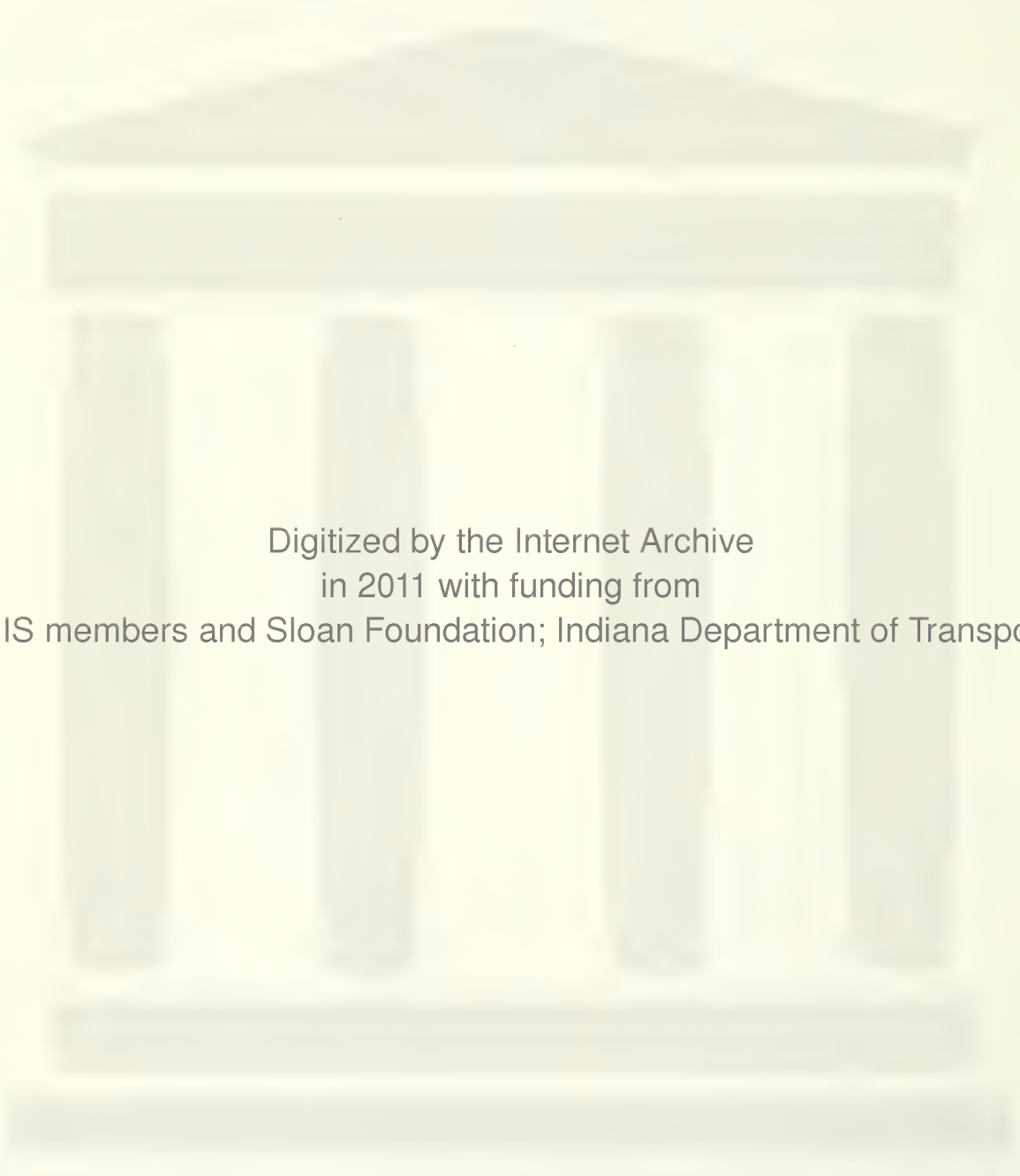
Respectfully submitted,

Harold L. Michael

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Project No.: C-36-10G

File No.: 6-10-7

Prepared for presentation at the
Annual Meeting of the
Highway Research Board
January 1973

Research Conducted by
Joint Highway Research Project
Engineering Experiment Station
Purdue University
In Cooperation With
Indiana State Highway Commission

Purdue University
West Lafayette, Indiana
December 28, 1972

ABSTRACT

Data are presented showing that small thicknesses of foamed plastic insulation prevented frost penetration into a highway subgrade in an area where the freezing index is less than 1000 degree days. The data were obtained from a test road (flexible pavement) built in northern Indiana, which consisted of: a control (normal) section with no insulation; the normal section plus 1 inch of insulation; and the normal section with the 6-inch subbase eliminated and 1 1/2 inches of insulation added.

Analysis of the five-variable subsurface temperature problem was conducted, holding three of the four independent variables, viz., three-dimensional subspace and time, constant, while examining the effect of the fourth on temperature.

Additionally, limited data are presented with respect to differential surface icing of adjacent insulated and uninsulated sections. The information indicates that the insulated pavements are colder during a seasonal cooling, while the uninsulated ones are colder during a seasonal warming.

The overall performance of the insulated sections is satisfactory after 3 winters of service.

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INTRODUCTION

Foamed plastic has become an effective means of preventing frost penetration into a highway subgrade. There have been a number of installations (1) built in various northern states of the U. S. and in Canada, areas where winters are very severe. In 1969, to study the effects of subgrade insulation in a more moderate climate, an insulated test road was built in north-central Indiana, where the freezing index is generally less than 1000 degree days. The test installation was under the direction of the Joint Highway Research Project, a cooperative effort of Purdue University and the Indiana State Highway Commission. The road was instrumented, and two years of data have now been collected. It is the intent of this paper to summarize the performance of an insulated highway in an area where the frost problem is less severe than those areas previously studied.

LOCATION AND DESIGN

The test installation is on Indiana State Road 26, approximately 13 miles east of Lafayette, Indiana and Purdue University, and is located just west of the Rossville, Indiana town limits.

A finite difference solution of the two-dimensional heat flow model developed at Purdue (3) was utilized in the design of this test installation. This method of design allowed possible design combinations to be easily checked by subjecting them to actual design year conditions. The design year was the 1962-63 winter, the coldest of the 10 years preceding 1969, having a freezing index of 1274 degree days.

Plan and profile views of the test sections are shown in Figure 1 and Figure 2, respectively. Section C is a normal (control) design section.

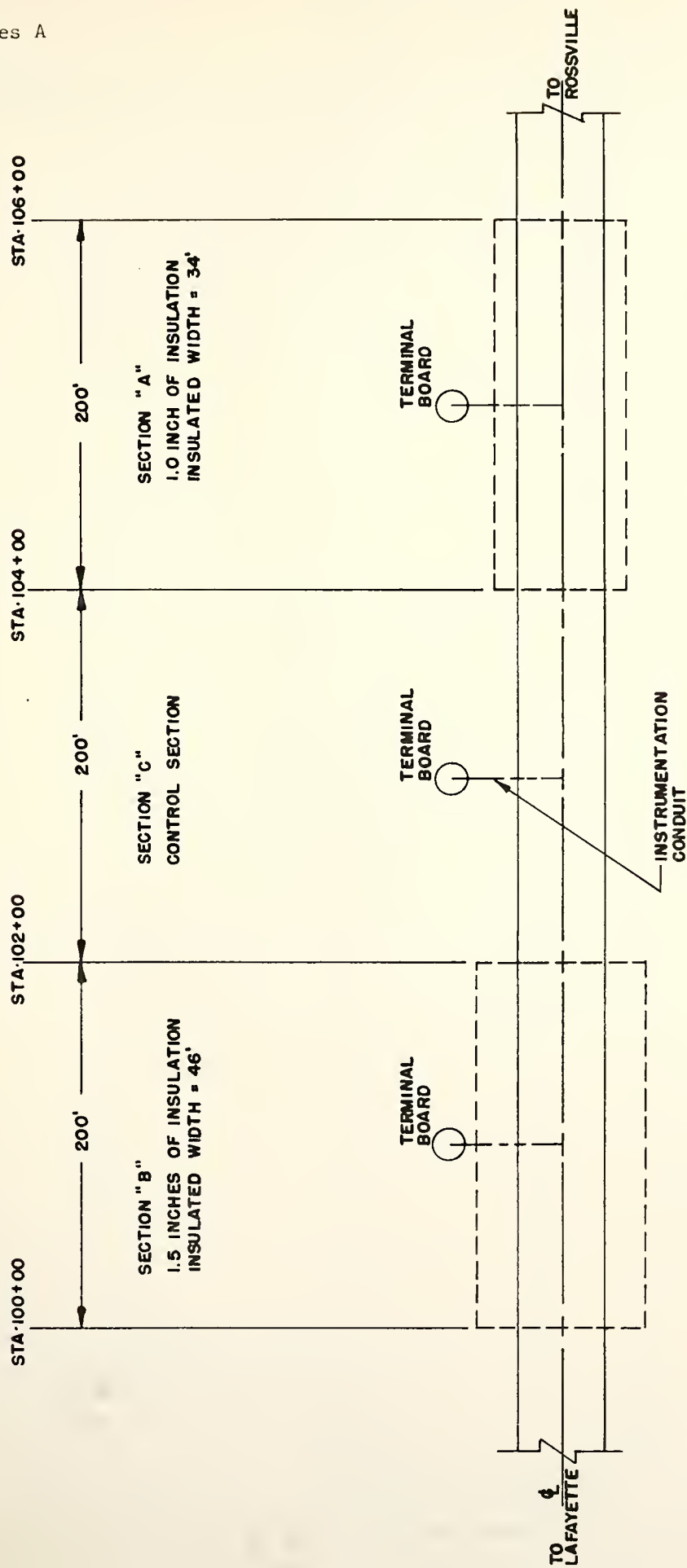
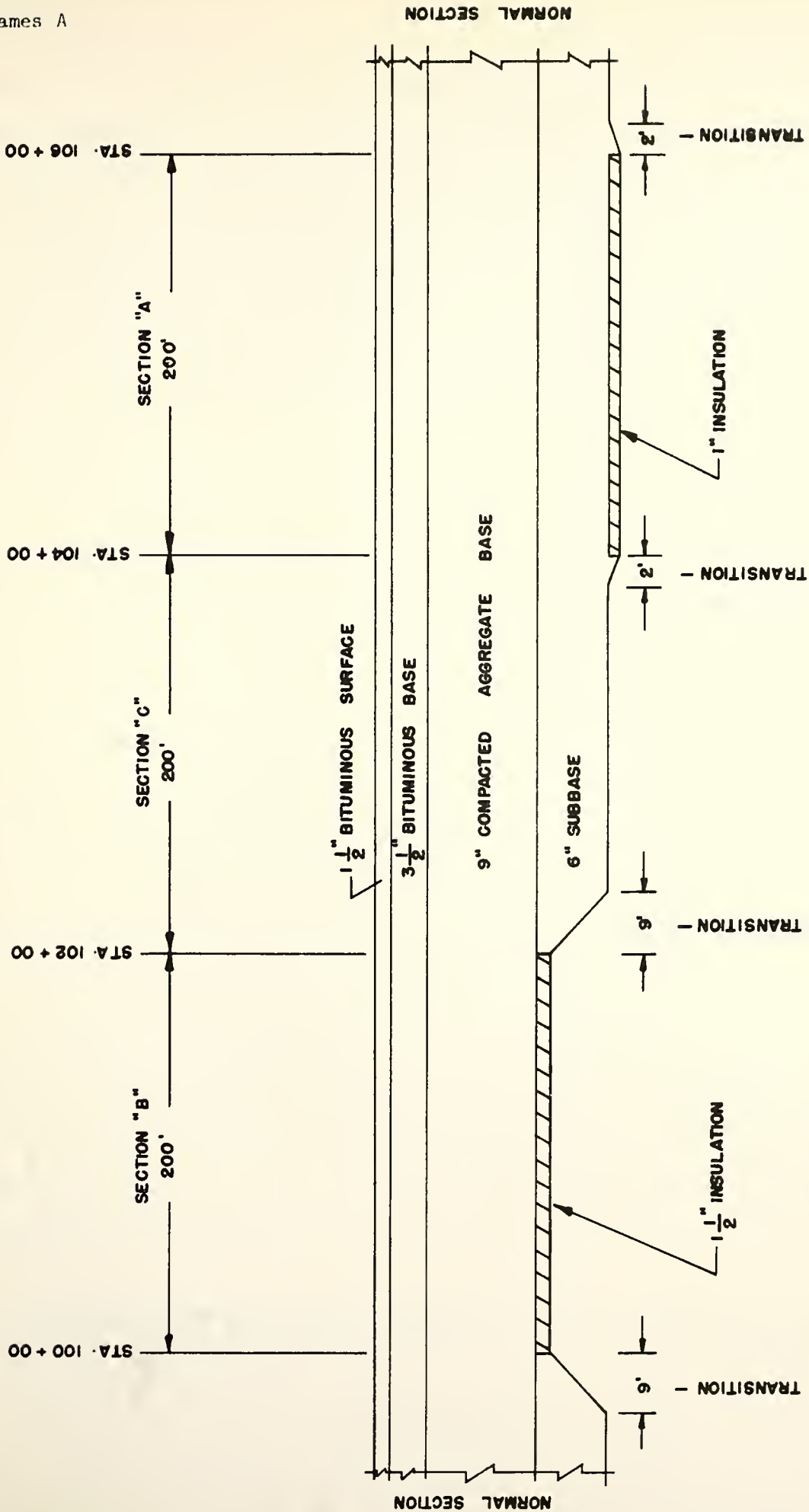


FIGURE 1

NOT TO SCALE



NOTE: ALL TRANSITIONS AT 1 1/2" PER FT.

FIGURE 2

NOT TO SCALE

Section A is the same as Section C except for a 1-inch thick, 34-feet wide layer of insulation¹ placed on the subgrade surface. The subbase was eliminated in Section B and a 1.5-inch thick, 46-feet wide layer of insulation was placed directly beneath the base course. The temperature sensors, thermistors, are located at the center of each 200-feet long section. The thermistors are installed only in the north half of the highway. Figures 3, 4, and 5 show the thermistor positions in Sections A, B, and C, respectively.

SITE CONDITIONS

Soil borings were located on the northern half of the highway at stations where the thermistors were placed. Also, soil samples were obtained at the time of thermistor installation from the sides of the installation trench, which was 4 feet in depth. From these investigations the soil profile and moisture conditions were determined.

The subgrade soils of Section A are 4 feet of A-2-4 soil (AASHO classification) overlying more than 8 feet of A-1-b soil. The water contents of the soils were found to be about 5% to 6%. The water table in Section A was found about 14 feet below the pavement surface. The borings in Section A were the only borings in which the water table was encountered. The borings in each section were from 11 feet to 15 feet deep. Section B soils consist of 1 foot of A-2-4 soil overlying 3.5 feet of A-4 soil which overlies an A-6 soil. The water contents were 5%, 13%, and 17%, respectively. Section C soils generally consist of 1.5 feet of A-2-4 soil overlying A-1-b soil. There is an additional layer of A-1-a soil about 6 inches thick located 2 feet below the top of the subgrade. The Section C water contents were from 5% to 7%.

1. The insulation is Styrofoam HI, manufactured by the Dow Chemical Company of Midland, Michigan.

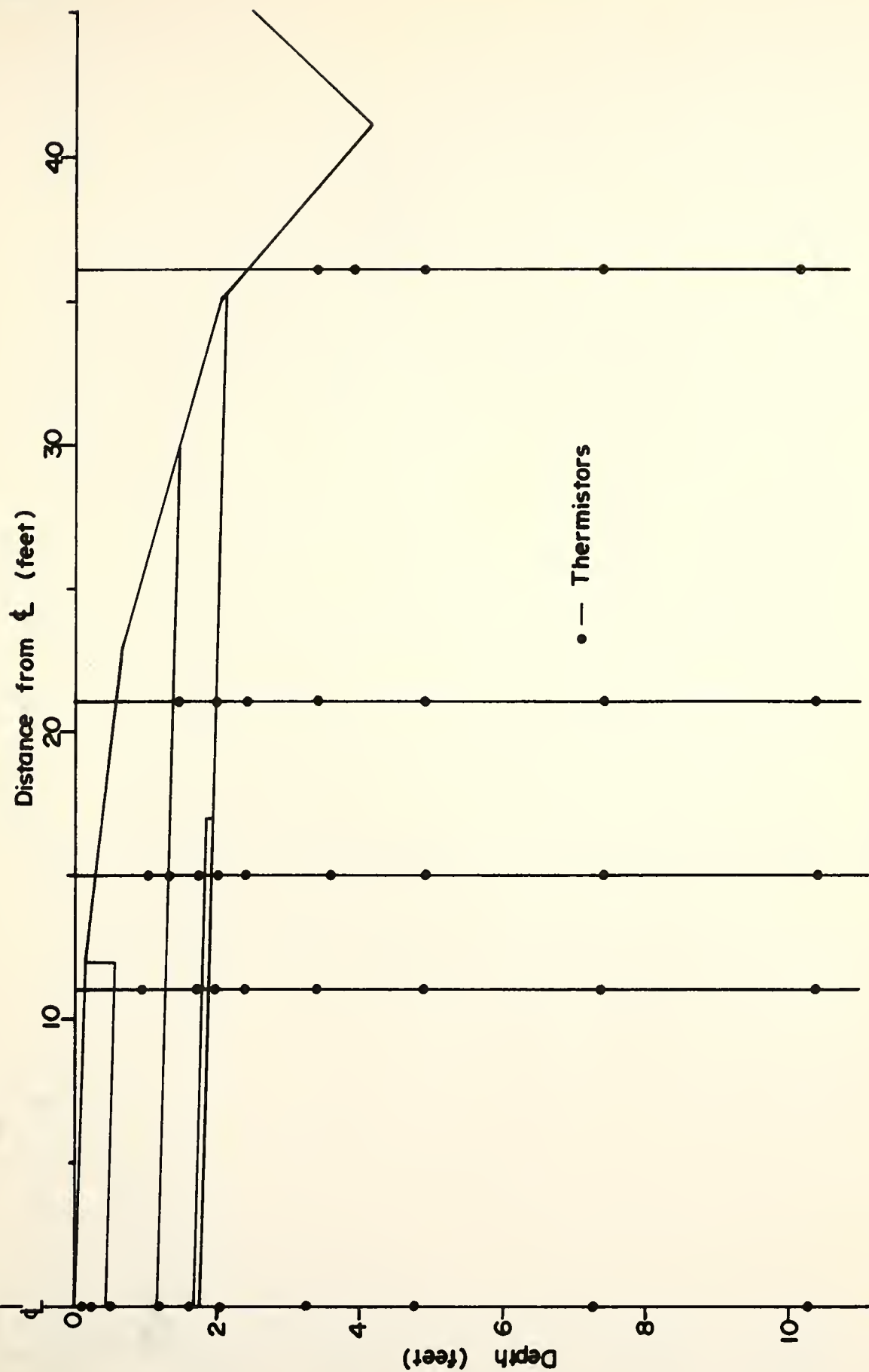


FIGURE 3

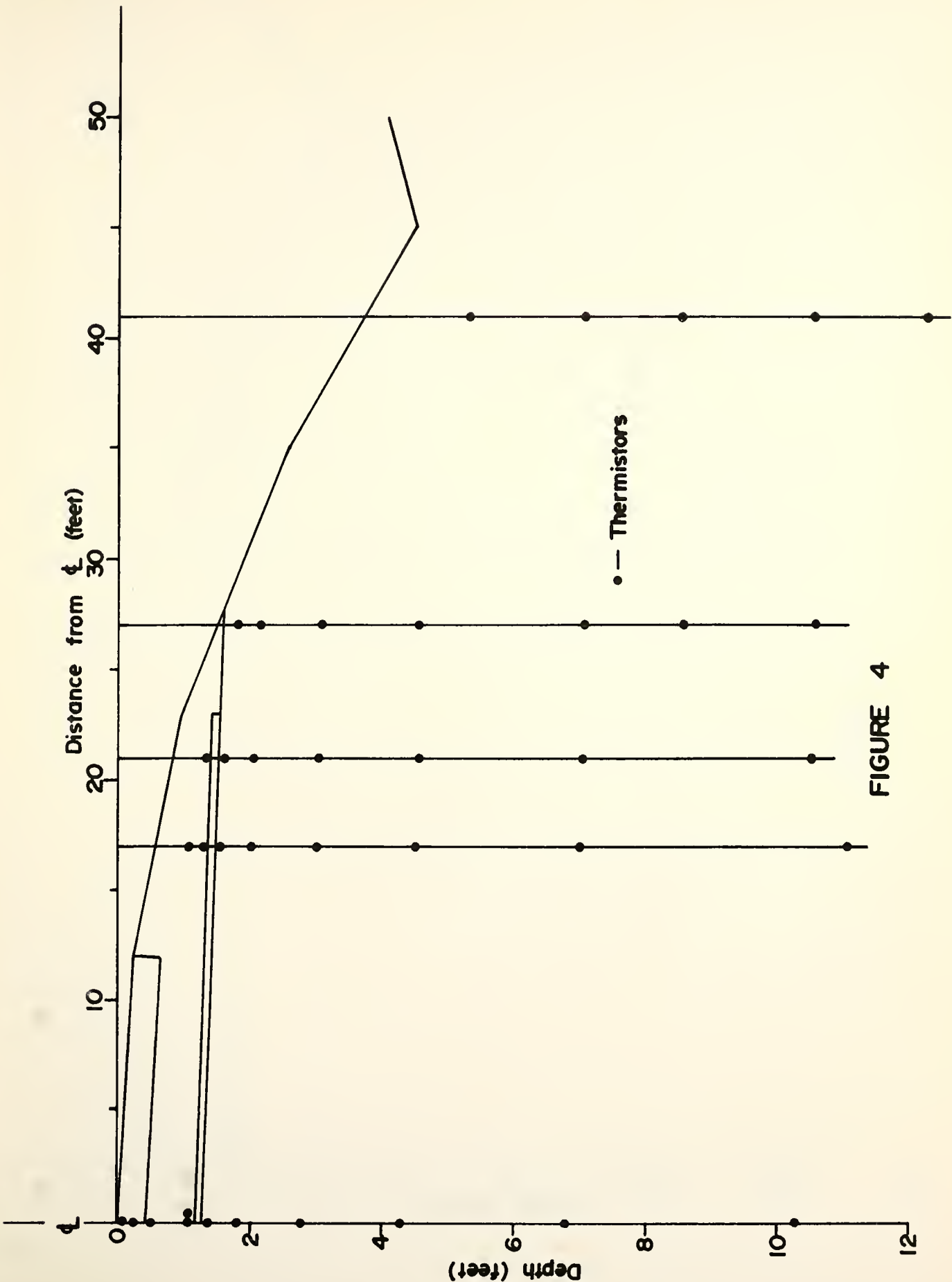


FIGURE 4

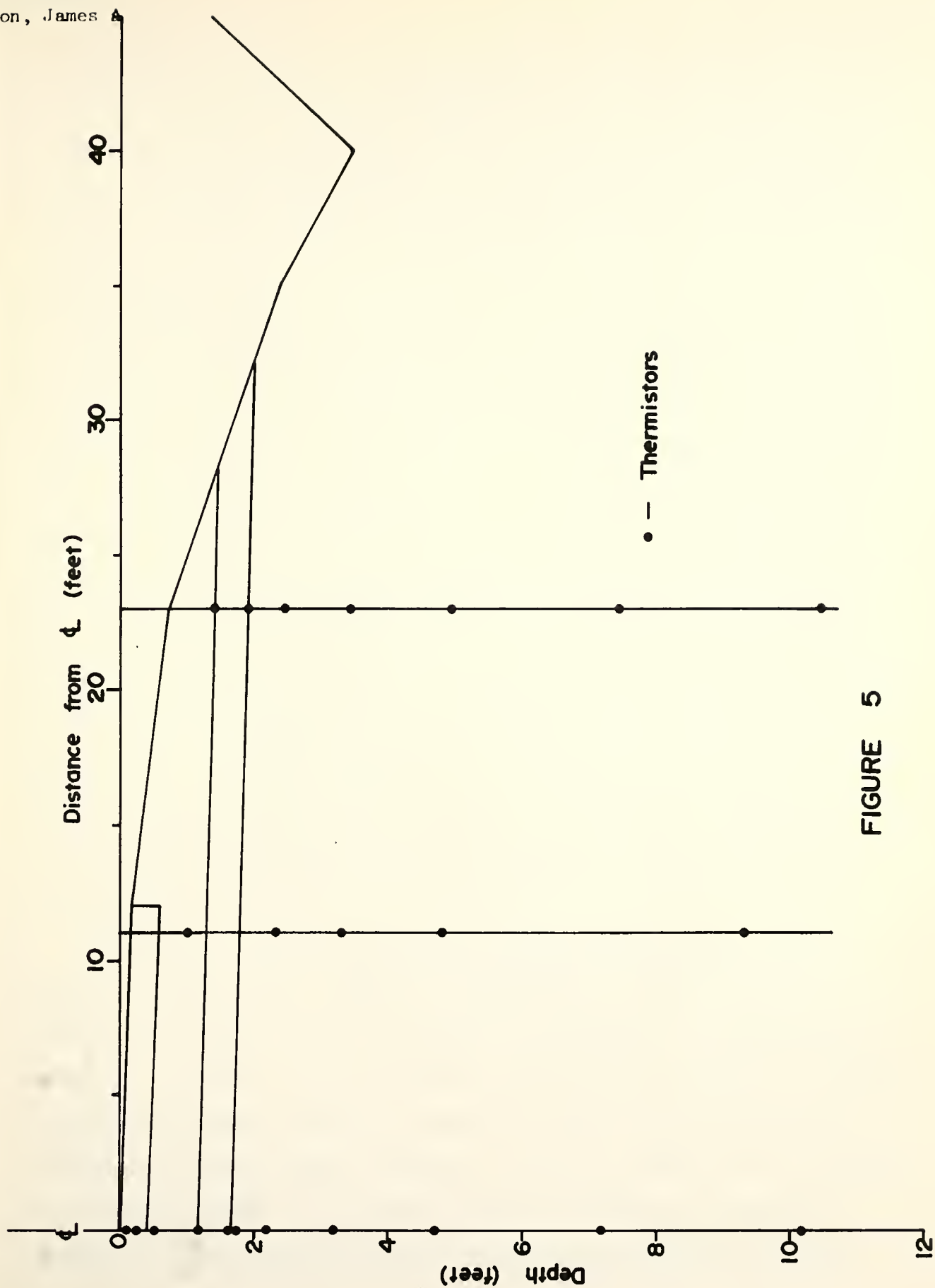


FIGURE 5

The site was selected in an area of generally silty soils, and was placed in a cut to increase the wetness (relative to a fill). Unfortunately, neither soil nor water conditions were such to produce hoped-for high-frost-damage potential. In spite of this, nearly all of the objectives of the study were realized.

PERFORMANCE EVALUATION

Indiana State Highway Commission Research and Training Center personnel collected data at the test installation during the winters of 1969-70 and 1971-72. First year data were collected every working day. Finding that lesser amounts of data could adequately define the trends, the 1971-72 data were collected twice a week except when sudden or extreme periods of cold dictated that additional data were required. The freezing indices of the 1969-70 and 1971-72 winters were low, viz., 673 degree days over a freezing season of 65 days and 355 days over a freezing season of 52 days, respectively.

The analysis of subsurface thermal patterns is a five-variable problem. Temperature is the dependent variable with time and with the three-dimensional subsurface space. The analysis of this paper is conducted by holding three of the independent variables constant and studying the effect of the fourth on temperature.

In Figures 6, 7, and 8, position (in 3-dimensional subspace) is held constant. Figures 6 and 7 compare the temperatures at points below the insulation in Sections A and B with points at approximately the same depth in Section C. The effect of the insulation is clearly seen in Figure 6. Section B, having the thicker insulation, remains the warmest of the three sections throughout the freezing season. However, care must be exercised when comparing the sections in Figure 7. The combined effect of different thicknesses of insulation, and the points considered being at different depths, make direct

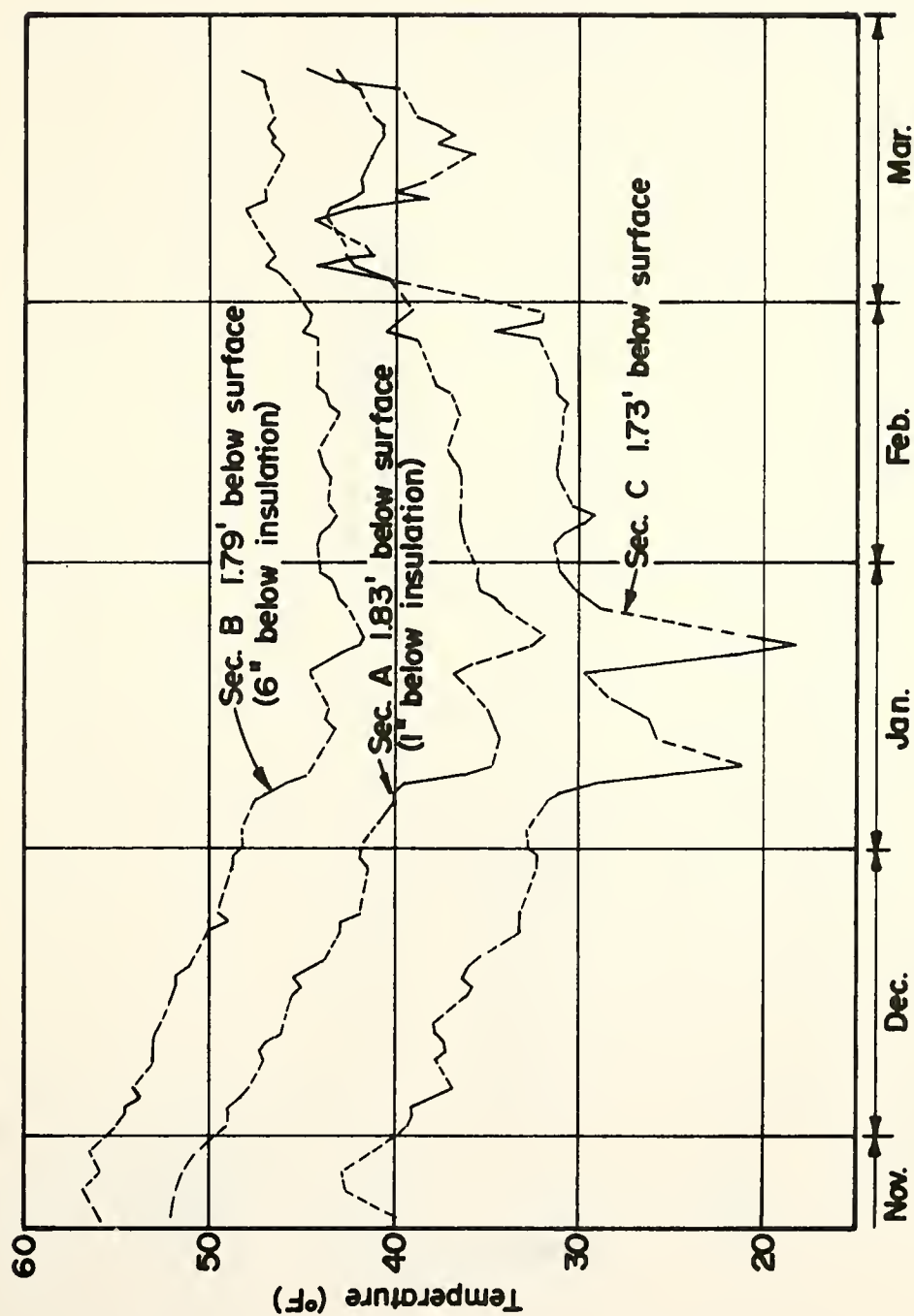


FIGURE 6.

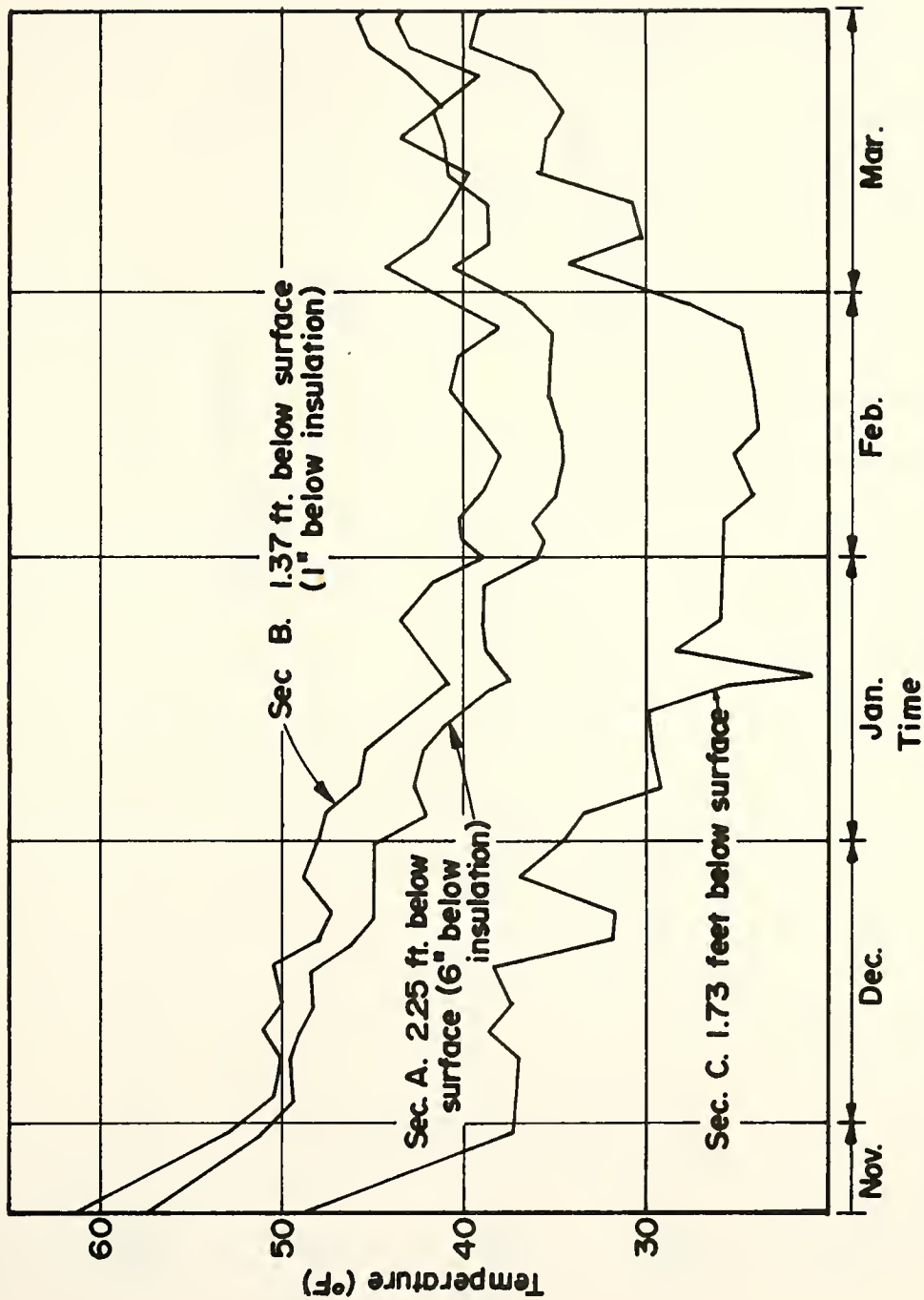


FIGURE 7.

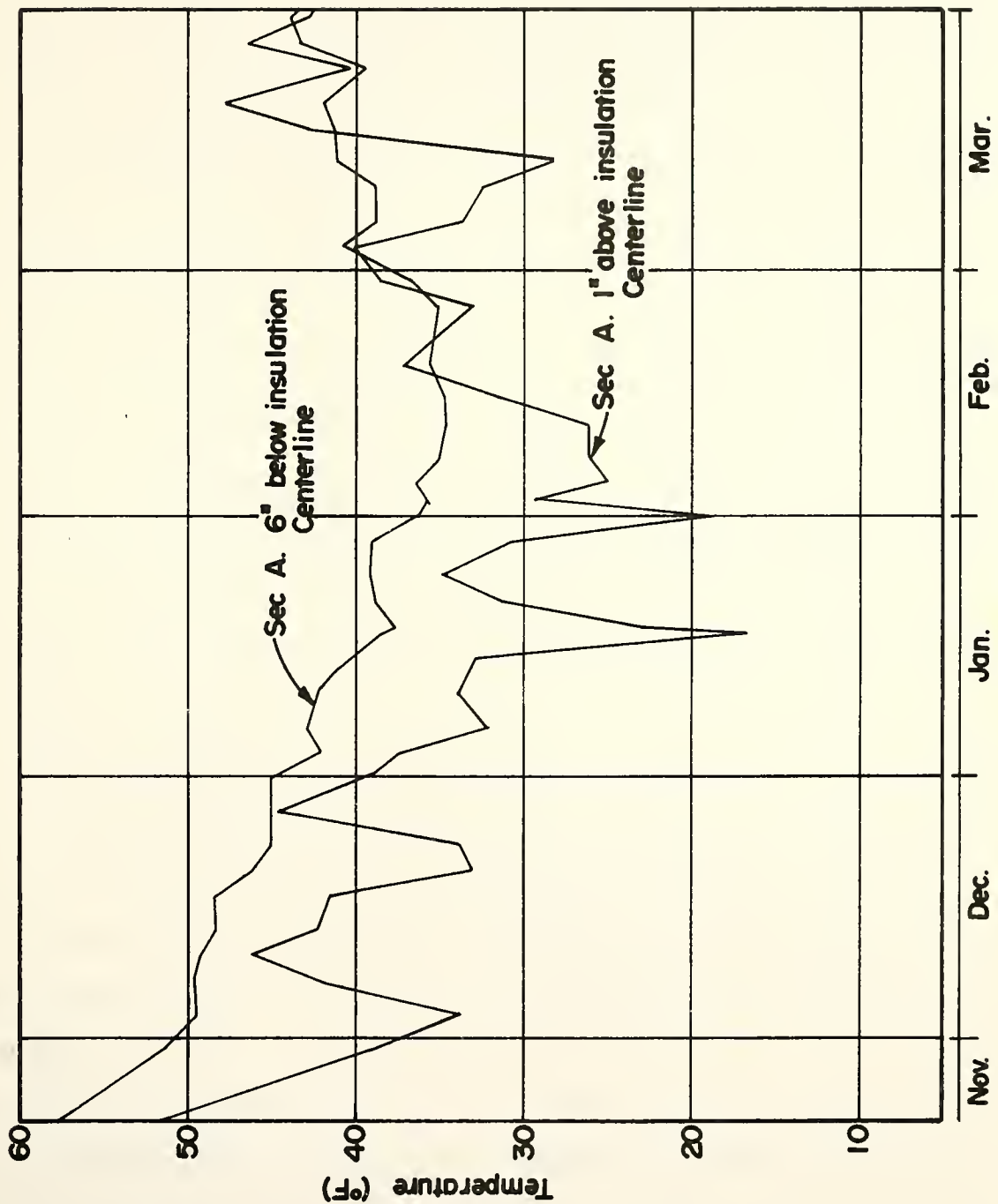


FIGURE 8

comparison difficult. Comparison of different depths was dictated by the loss of some instrumentation during the three years of service. By hypothetically assuming a vertical thermal gradient, i.e., no temperature change, from the depth of the point observed in Section B to the same depth as observed in Section C, it can be resolved that the Section B subgrade is again warmer. The effect of the insulation can also be seen in Figure 8, where the temperature above and below the insulation in Section A is compared. The 1 inch of insulation was enough to allow the subgrade to remain unfrozen while the temperature directly above the insulation was as low as 17°F .

In Figures 9, 10, and 11, isotherms for each of the three sections are shown for January 20, 1970, approximately the time of maximum frost penetration in the control section during 1969-70. For the uninsulated section, the isotherms are approximately parallel to the ground surface, which is intuitively expected when there is little lateral variation of soil properties and no snow cover. In Sections A and B, the insulation modifies both the shape and the magnitude of the isotherm at a given depth. Again, the effect is greater for Section B.

Another convenient means of illustrating the effect of the insulation is to plot temperature gradients (temperature vs. depth curves), as shown in Figure 12 for January 22, 1970. It is important to note that Section B, besides again having the warmest subgrade temperatures, has the coldest pavement temperatures. This effect will be discussed in more detail later in the paper.

The depth of penetration of the 32° isotherm in Section C for the 1969-70 freezing season is shown in Figure 13. Although the penetration was to a depth of 4 feet in Section C, the 32° isotherm did not penetrate the insulation in either Section A or Section B.

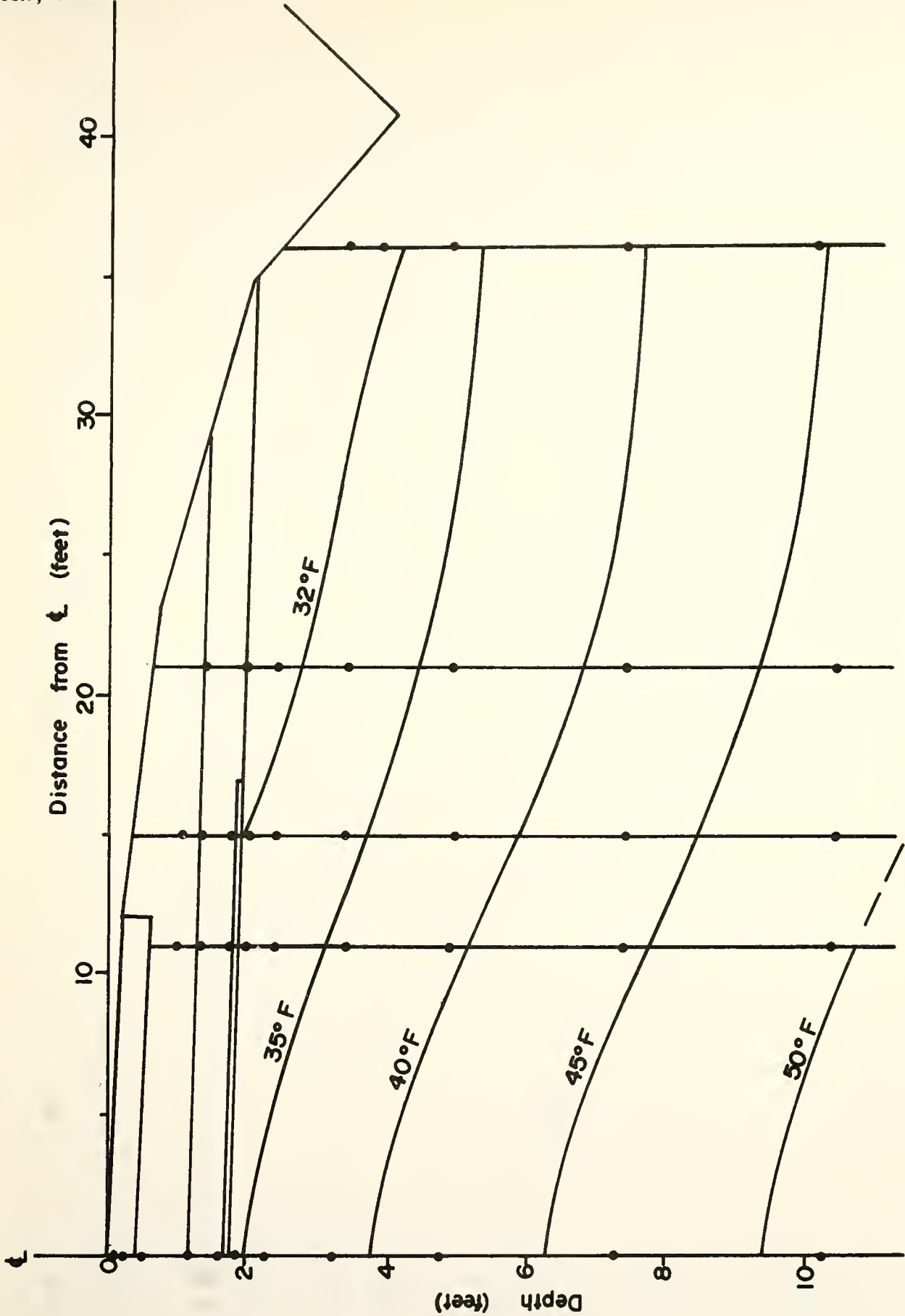


FIGURE 9.

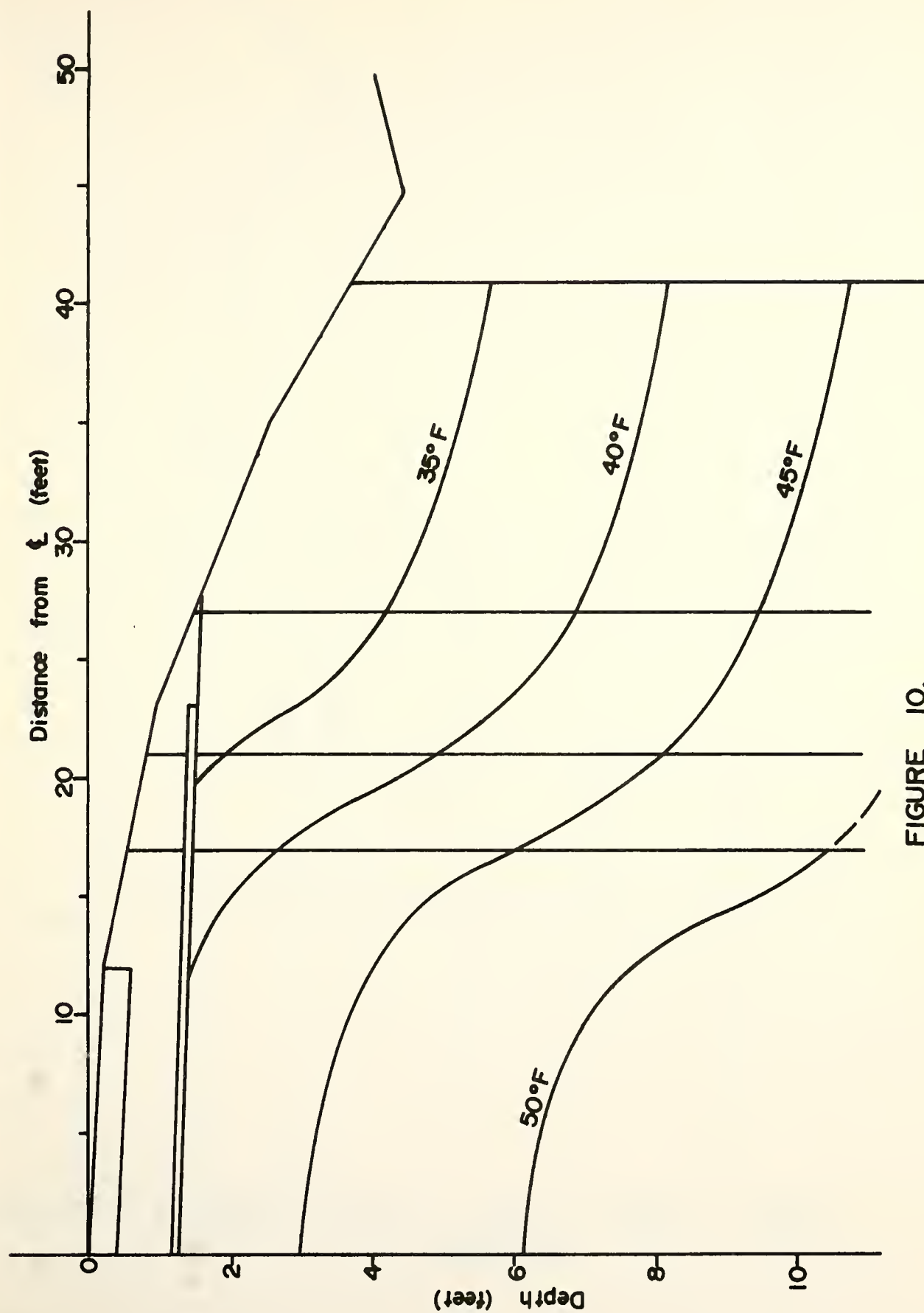


FIGURE 10.

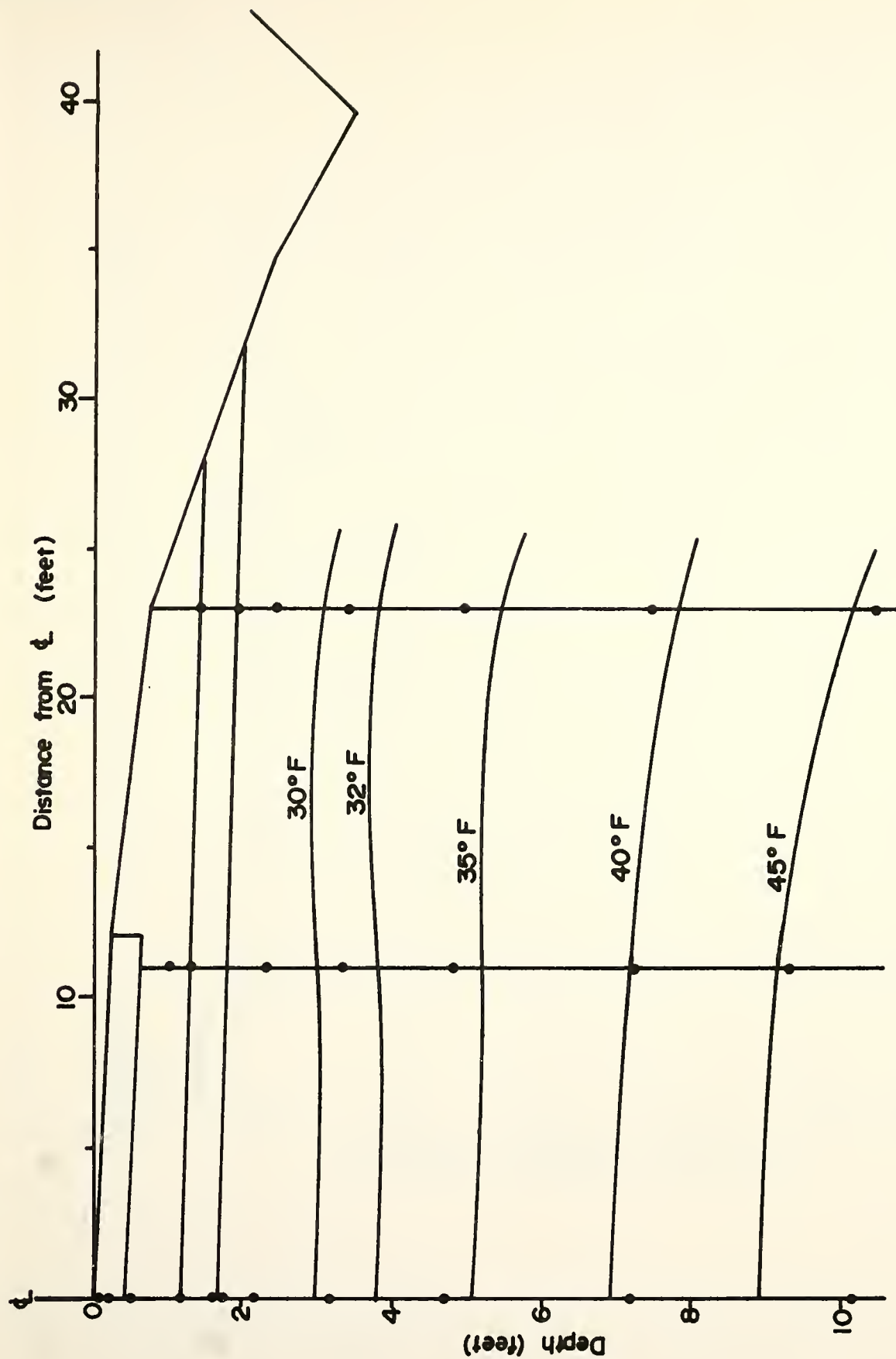


FIGURE 11.

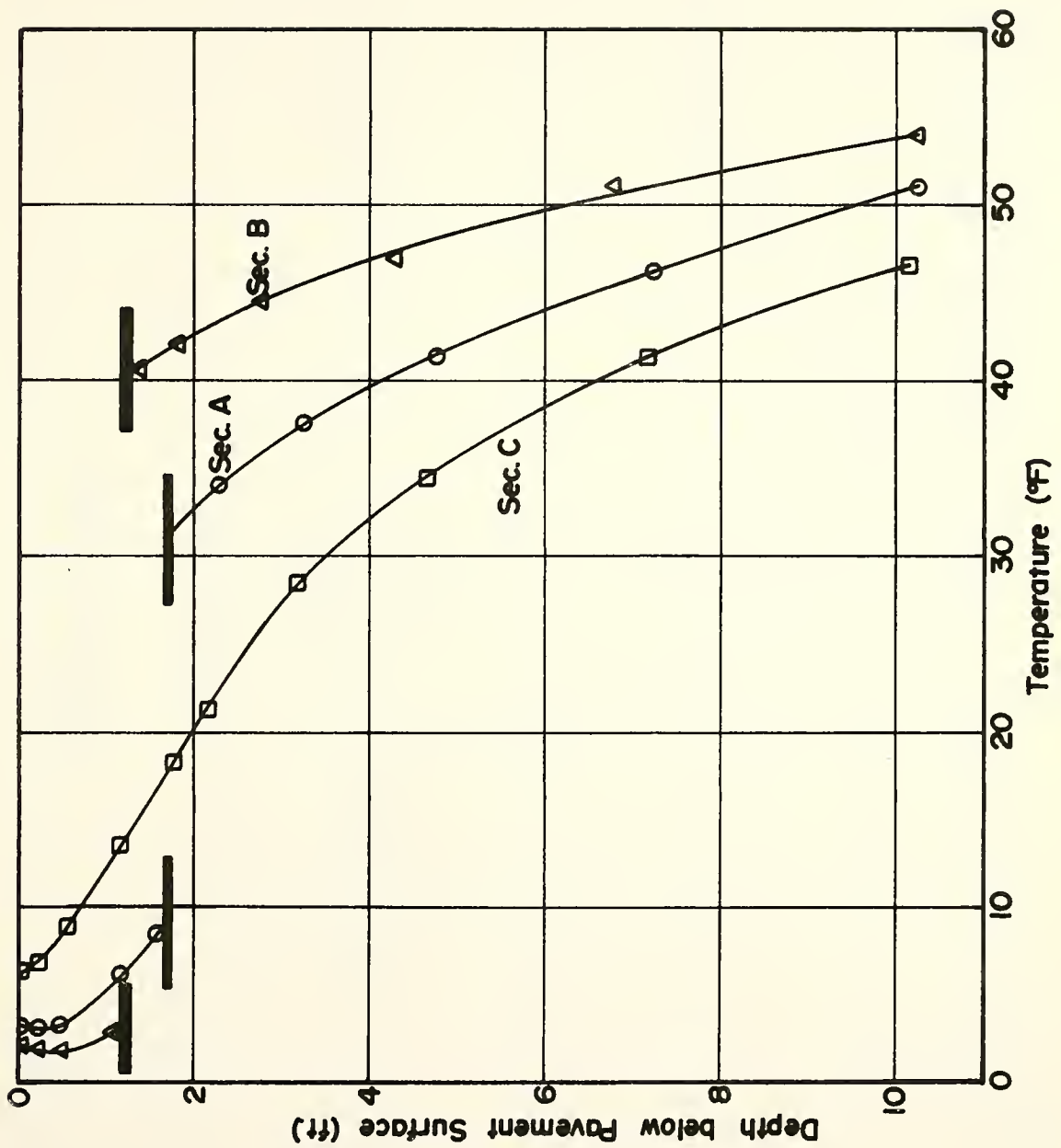


FIGURE 12.

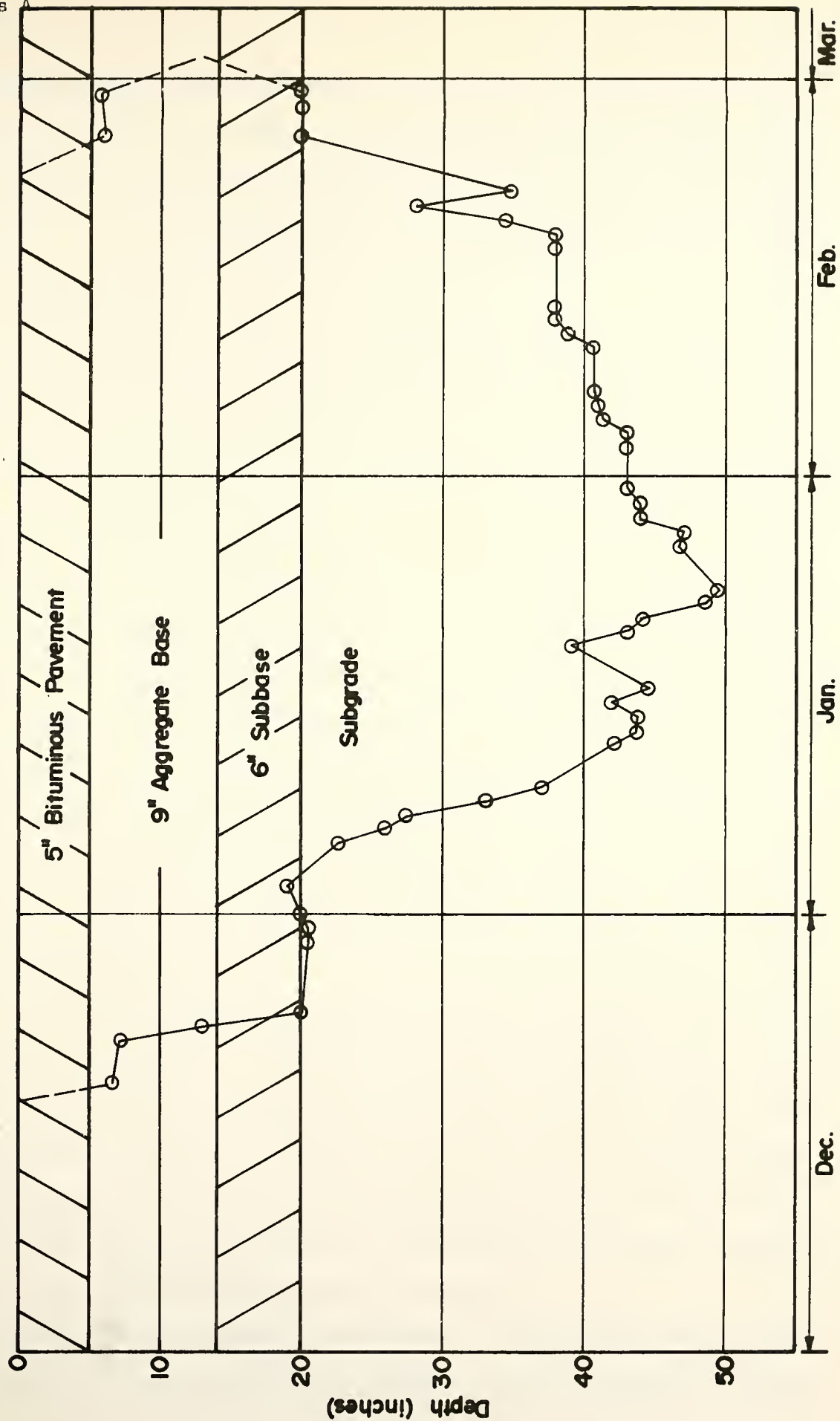


FIGURE 13

Some transverse and longitudinal cracking of the bituminous surface has developed on the test sections, but the cracking is consistent with cracking that has occurred outside the limits of the test site. Thus, it does not seem likely that the insulation has lead to any poor structural performance.

ICING POTENTIAL STUDY

It is known that the presence of an insulation layer will alter the normal heat flow through a pavement. A potentially troublesome side effect of subgrade insulation, when used in sections of limited length, is a differential in the temperature of the adjacent pavement surfaces of insulated and uninsulated sections which can lead to preferential icing of these surfaces. Shown in Figures 14 and 15 are the temperatures of points 1 inch below the pavement surfaces in Sections B and C for 1969-70. The general trend of the Figures is that the pavement system above the insulation may be either cooler or warmer than an adjacent and similar uninsulated system, depending upon whether the air temperature is in a general cooling trend or a general warming trend.

An attempt was made to visually determine any degree of differential icing on the test road during 1971-72. The distance of the test installation from Purdue University limited this study to a random daily observation of the pavement condition.

No differential icing was encountered during the survey, but some difference in behavior was observed. On a number of occasions, the insulated sections were darker in color due to the presence of moisture in the minute surface cracks of the asphaltic surface. The reverse situation was also seen when, during a light snowfall, the insulated sections remained dry due to the snow being blown off the colder surface, while the snow melted on the warmer uninsulated section, causing the pavement surface to be slick.

The findings of this study with respect to differential pavement icing are inconclusive for several obvious reasons. However, generally, and with

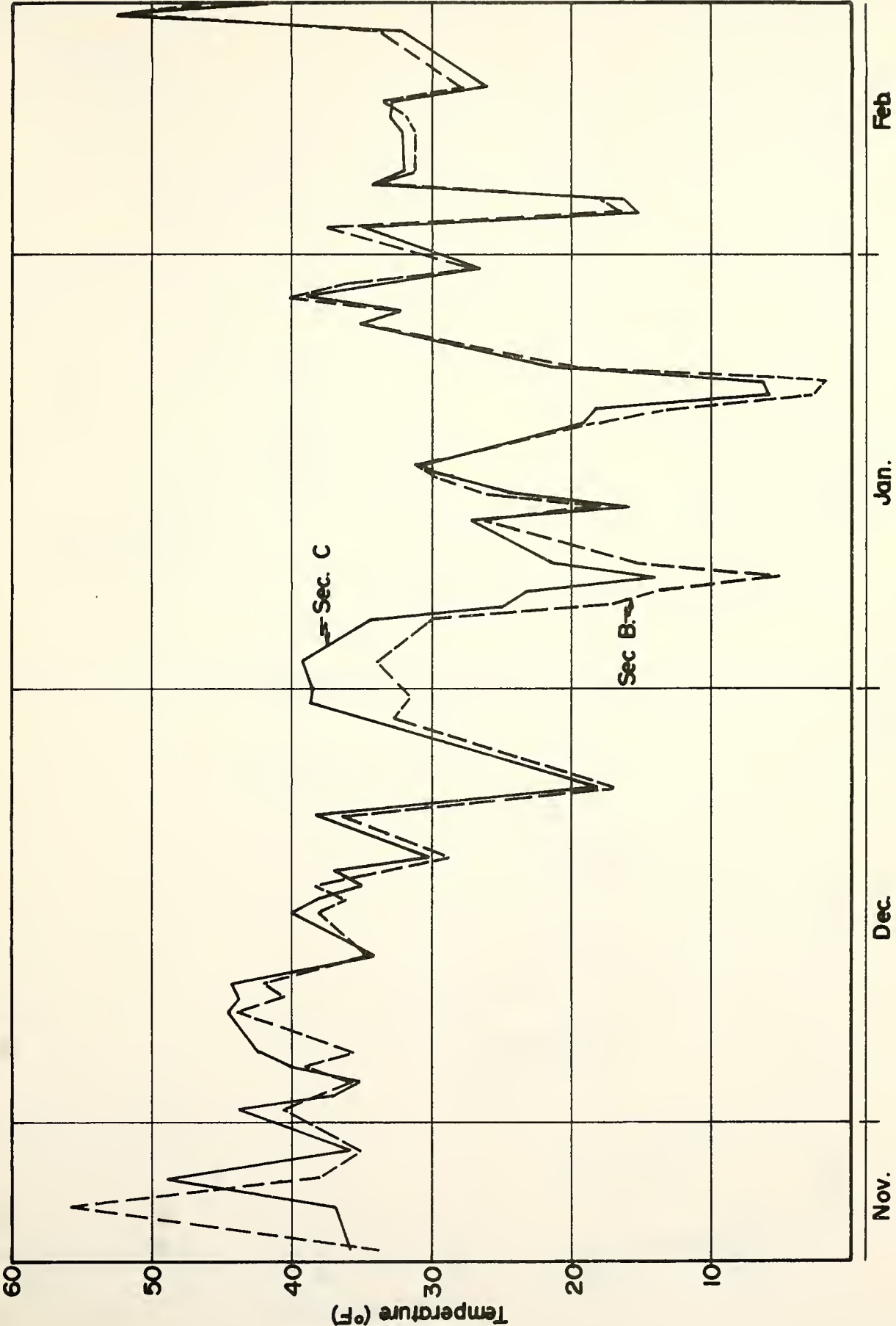


FIGURE 14

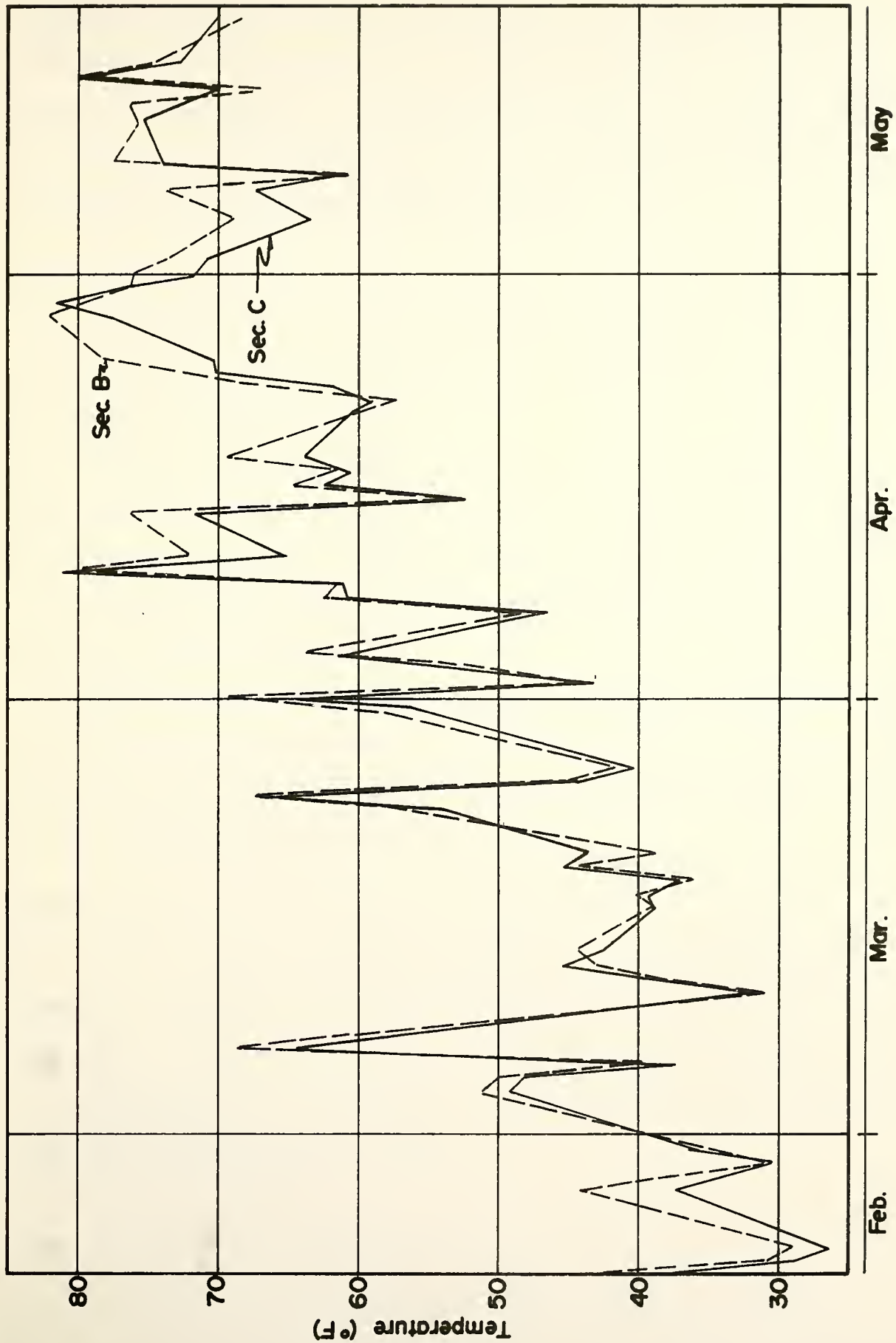


FIGURE 15

reference to Figures 14 and 15, the tendency for an insulated section to ice with respect to an uninsulated one (or vice versa) depends upon the general trend of air temperatures. In a general cooling trend, the insulated sections are more likely to have surface ice, while in a general warming trend, the uninsulated sections are more likely to have ice.

CONCLUSIONS

Data have been presented to show that small thicknesses of insulation, viz., 1 inch and 1.5 inch, were sufficient to prevent subgrade frost penetration in areas of low freezing indices.

Although no surface icing was encountered during the study, it is inadvisable to conclude that icing is not a problem, due to the limited number of pavement observations. In general, the insulated sections are more likely to ice during seasonal cooling, but the uninsulated ones are more likely to ice during seasonal warming.

The two-dimensional heat flow model is an effective thermal design tool, in that combinations of thickness of insulation and depth of placement may be compared with relative ease, and for each the appropriate combination selected for the specific design situation.

ACKNOWLEDGMENTS

The authors wish to thank the personnel of the Indiana State Highway Commission Research and Training Center under the direction of Mr. H. R. J. Walsh for their perseverance in the collection and reduction of data.

Also appreciation is expressed to the Joint Highway Research Project for financial assistance during the study.

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